36. Additional Notes *on the* Glacial Phenomena *of* Spitsbergen. By E. J. Garwood, Esq., M.A., F.G.S. (Read June 21st, 1899.)

[Plates XLI–XLVIII.]

I. Introduction.

In a paper published in the preceding volume of this Journal,[1] an account was given of the glacial phenomena observed in Spitsbergen by Dr. Gregory and myself during our visit with Sir Martin Conway in 1896. The work accomplished that year was practically confined to observations made in the valleys lying to the east of Ice Fjord, namely Advent Vale and Sassendal, with their tributary glens and connecting passes. Over this district there is no approach to a continuous sheet of ice; our detailed investigations were therefore limited to an examination of the small glaciers occurring over restricted areas, or debouching into the larger lateral valleys, from the icefields to the north. The time at our disposal that year did not admit of an expedition on to the inland ice, marked in the chart as occurring farther north, of which we caught glimpses on more than one occasion from the summits of the Sassendal peaks. From the views, however, which we obtained, this district promised to afford admirable material for the study of ice-action on a large scale. As no information could be procured regarding the character of the interior of the northern part of West Spitsbergen, save that the chart bore the mysterious legend 'high inland ice,' a term which we had found on previous occasions to be synonymous with 'unexplored,' I decided to revisit the island, and was fortunate in persuading Sir Martin Conway to join me on an expedition during the summer of 1897 into the interior of the country lying north of Ice Fjord.

The objects of the expedition also included the exploration of the mountain-ranges in the neighbourhood of Horn Sound, situated at the southern end of the island, from which I had been driven back by bad weather the previous year.

The geographical results obtained have already been published.[2] The present communication records observations made on ice-action in the districts which we traversed during this expedition.

II. The Inland Ice.

The tracts of ice which we visited are described as 'high inland ice' in the old chart of Spitsbergen, and occupy two distinct areas. The larger of these covers a tract of elevated ground lying between N. lat. 78° 30′ & 79° 10′, and E. long. 16° & 20°.

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[1] Vol. liv (1898) p. 197. A full list of references to previous work on ice in Spitsbergen and kindred districts elsewhere will be found in the paper quoted.

[2] Geogr. Journ. vol. xii (1898) p. 137.

The other tract lies immediately to the west of this, and occupies the greater part of King James's Land; they are separated one from the other by Dickson Bay and Wijde Bay and by the depressed area which connects these inlets (see Map, Pl. XLI).

The expression 'inland ice' is a vague geographical term, useful perhaps when applied generally to a country in which land-ice predominates, but which has been neither mapped in detail nor differentiated into separate glacier-systems. For strict accuracy, however, the terms 'ice-sheet' and 'glacier' convey a more definite meaning. Though I am not aware that an ice-sheet has ever been scientifically defined, most writers appear to use it in the sense of a complete covering of ice, radiating from a watershed consisting of snow and ice, and not confined or directed by visible barriers of rock, while a glacier, though it may originate in an ice-sheet, occupies a definite valley. As thus defined, a small ice-sheet does exist on each of the above areas, the radiating-point and chief gathering-ground being situated somewhat north-west of the centres of each area, with supplementary radiating-points to the north and east. If we accept this view, the rock-ridge of Mount Chydenius, in the eastern tract, and the group of peaks including the Three Crowns protruding above the ice in the centre of King James's Land, may be regarded as groups of nunatakkr, though, in the latter case, the system is extremely complicated (see panorama, Pl. XLII). There can be no doubt, however, that, whether this application of the term 'ice-sheet' is accepted or not, the effect produced is practically the same as that which would result from the presence of a much more extensive sheet. We have here a district from which the ice-cap, which once buried it more deeply, is gradually melting off: the melting has not, however, yet progressed sufficiently to have reached the Alpine-glacier stage, and we still have undoubtedly the effects of an ice-sheet with its valley-bound ground-ice and freely moving surface-layers, with the result that the latter travel in an independent direction, frequently at right angles to the former. The district has, however, reached a stage in its history when the original central surface radiating-point has been replaced by several separate decentralized points by the lowering of the ice-surface and the obstruction offered by a constantly increasing number of nunatakkr.[1] Here is in fact a condition of things almost identical with that which obtained in our own country, on the land-ice hypothesis, during the Glacial Epoch. As the cold conditions passed away and the ice-sheet covering Britain melted off, the radiating-point must have been replaced by decentralized points in a similar manner; and this fact is perhaps not sufficiently borne in mind in accounting for such phenomena as the intercrossing of the erratics in many of our own glaciated districts.

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[1] A careful examination of the nunatakkr met with during the expedition across these ice-sheets revealed nothing unexpected as regards their flora. The plants all belong to the more universally distributed species collected on the coast and in the ice-free valleys, such as *Saxifraga oppositifolia*, *Papaver nudicaule*, *Dryas octopetala*, etc.

III. Surface-phenomena of the Ice-sheets.

Although in some respects the surfaces of these ice-sheets are not the best place to observe the action of ice, they are not without their points of interest. In the upper portion near the radiating-points the slope of the surface is gentle and snow-covered, becoming, however, wavy and undulating as it approaches a nunatak; in places also eddies may be observed, distinctly comparable with the swirl of river-water in the neighbourhood of submerged rocks, so that, even where no rock is visible above the ice, the presence of buried mountain-ridges may be often inferred. In immediate proximity to a group of nunatakkr the ice is frequently much crevassed, especially towards the lee side of the obstruction, the fissures representing true marginal crevasses as the direct result of differential ice-movement. Glacial lakes are also of frequent occurrence here. On the impact-face[1] of a nunatak the ice is much compressed and rises considerably above its average level (Pl. XLVI, fig. 2). This is undoubtedly due to the retardation of the lower layers, and the increased shear-friction produced in the upper ones: this surface-swelling therefore corresponds to the raised lip which surrounds the snouts of many of the glaciers of the country when advancing or when impeded by their old moraines, as previously described.[2]

In connexion with this compression of the ice in the neighbourhood of the nunatakkr, an interesting phenomenon is sometimes noticeable which does not appear to have been previously described.

When any crevassed portion of the ice-sheet is thrust against such an obstruction, the pressure brought to bear causes the crevasses to close, and an interesting peculiarity in the constitution of the bridges that span the crevasses is forcibly brought to notice. These bridges, instead of consisting of snow as do those which occur in Swiss glaciers, are composed of solid ice, the result of continuous melting in the summer and the action of severe winter-frosts. When therefore the walls of the crevasse are reunited, the ice-bridge which spans it is squeezed upward into the form of an arch which finally becomes a complete tunnel: these may be seen not infrequently running in parallel sets for long distances (Pl. XLVI, fig. 1); being broken in places, water readily obtains access to them, and it is not an uncommon occurrence to find these tunnels being made use of as drainage-channels for the surface-water of the district. One of the most striking instances observed by us occurred where the drainage from the Devonian shales forming the flank of a nunatak coursed in a blood-red stream between the blue translucent walls of a tunnel of this description (Pl. XLV).

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[1] There being no recognized English equivalent in general use for the stossseite of the German geologists, I have ventured to use for it the term impact-face throughout this paper, since it commended itself to me as a fairly accurate and expressive substitute.

[2] Quart. Journ. Geol. Soc. vol. liv (1898) p. 208 & pl. xviii.

Another interesting point to be noticed in connexion with these nunatakkr is their effect on the englacial moraines brought down by the ice-sheet. In several cases where a nunatak protruded from the ice, the overriding of the upper layers and the heaping-up of the ice on the impact-face of a nunatak caused the moraine-material, interstratified in the lower layers of the ice, to be brought up and deposited on the surface in a manner similar to that recorded in connexion with the Greenland ice-sheet.[1] (See Pl. XLVI, fig. 2.)

Attention is here called to this action, because it appears probable that the upward motion of this material is produced in identically the same way as was shown to occur in the case of raised-beach material brought up by the advancing front of the Ivory Glacier in the paper previously cited,[2]—the obstruction exerted on the lower layers of the glacier by the ice-talus in the one case being represented in the other by the submerged portion of the nunatak.

Under this category I was at first inclined to place the material which forms one of the most interesting medial moraines of Nordenskjöld Glacier. It consists of a row of large rounded and polished blocks of hard Archæan granites, many of which are 4 to 6 feet in diameter. They could be seen stretching away up the glacier to its source in a large nunatak of Carboniferous rocks, which separates the main mass of the glacier descending from Mount Chydenius from the smaller glaciers to the south. These blocks were almost perfectly rounded, and occurred at intervals of many yards (Pl. XLVIII, fig. 2); they were entirely free from admixture of angular débris, and had undoubtedly travelled in or beneath the ice. They may have reached the surface by elevation against the nunatak as described above: unfortunately the thick weather which we encountered during the exploration of this ice-sheet prevented me from deciding this question; but, judging from a distant view which I afterwards obtained from the coast, I am inclined to think that they originated in a different way.

The blocks appear to belong to an earlier period of glaciation, when the ice-sheet covered much higher ground than at present, and had therefore a different radiating-point. During this period the blocks must have been stranded on the surface of the nunatak as part of the ground-moraine of the ice-sheet, and strewn over the surface much as are the hyperite-boulders observed by me 1500 feet up on the plateau of the Sassendal. As the disintegration of the Carboniferous rocks takes place, these Archæan blocks are hurled on to the glacier below, and travel down the ice parallel with the angular surface-moraine strewing the surface a little nearer to the side. We thus have a kind of fossil moraine again playing its part as a surface-moraine, at a distinctly subsequent period in the glacial history of the district.

The observations made in the previous year upon the elevation of loose material by the advancing front of the Ivory Glacier were borne out by phenomena of a similar character met with during this expedition. Wherever suitable material existed, it was invariably picked up by the sole of the ice and sheared up gradually through layer after layer till thrown out on the surface of the ice. I would especially mention the débris so thrown out by the ice on the south side of King's Glacier, and the englacial material brought up against the nunatakkr mentioned above.

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[1] 'Meddelelser om Grœnland,' pts. i–vi (1879–1883).

[2] Quart. Journ. Geol. Soc. vol. liv (1898) p. 205.

IV. Drainage of the Ice-sheets.

Where the ice-sheets are crevassed, as in the neighbourhood of nunatakkr, no surface-drainage really exists, but everywhere above the snow-line in summer, where the surface is unbroken, an enormous quantity of water is constantly set free. This accumulates to such an extent as to saturate the snow and form a spongy mass, into which the traveller frequently sinks even when supported on snow-shoes. This occasionally collects in some of the surface-eddies in the ice and forms lakes, especially in the hollows formed on the lee side of a nunatak. The resulting drainage gathers into rills and water-channels, and eventually into voluminous streams which, in King James's Land, have excavated channels several feet below the surface of the ice. These channels, with their treacherous banks, their slippery floors of hard blue ice, and their rushing torrents, occasionally form serious obstacles to the exploration of the ice-sheets. One of the interesting features to be noticed in connexion with these streams is the abundance of rock-fragments occasionally found in their channels; these are derived from morainic material, and during their passage downward become to some extent rounded and waterworn before being deposited lower down the valley.

In addition to surface-streams, englacial streams are also met with, and it is in connexion with one of these latter that the most suggestive deposits of this character occurred. About a day's march from the coast, on the left bank of King's Glacier, we found a very interesting example of an englacial stream, which originated in a lake formed annually on the lee side of a large nunatak. During the winter months the entrance to the channel was evidently blocked by snow, so that the water, formed by melting snow in spring, accumulated between the edge of the ice and the hollow formed on the lee side of the nunatak. As the summer advanced the snow-barrier melted away, and the water of the lake escaped with great impetuosity down what may have originally been a flaw in the ice, but which, when we saw it, was a tunnel 12 to 15 feet in diameter excavated in the solid ice. The direction of the tunnel ran at right angles to the direction of the valley and was plentifully strewn with moraine-material. This material was derived partly from angular fragments which constantly fell from the slopes of the nunatak, and partly from the englacial moraine dragged up to the surface by the pressure against the nunatak. The débris derived from both these sources had evidently been carried with great force along the tunnel during the bursting of the lake in the previous spring, and, when we saw it, still strewed the mouth and floor of the tunnel; the direction of this channel, as previously stated, was at right angles to the main lie of the valley, so that on the valley becoming free from ice, as the climate ameliorated, this waterworn glacial material would be deposited as a gravelly ridge, running roughly at right angles to the long axis of the valley and forming a kame. (See Pl. XLVII, fig. 2.)

V. Rate of Movement of the Ice. (Pl. XLIV.)

During our short visit to the interior we were unable to undertake any measurements to ascertain the rate of movement of the ice-sheets. From what we saw of them, however, I am inclined to think that the motion is not nearly so great as that of the glaciers near the coast. The rate of advance of these latter glaciers was not accurately measured; but, judging from observations made before and after our journey into the interior, I do not think that this rate can average less than 15 or 20 feet in every 24 hours. I have endeavoured to check this estimate by observations made on the size of the icebergs daily calved from the front of King's Bay Glacier. The bergs here do not appear to be produced by any strain on the ice due to a sudden fall in the ground along the edge of the coast, but are caused primarily by the action of the tides. As the tide rises, the upward pressure exerted by the water upon the submerged portion of the glacier-front forces off a narrow strip of ice which breaks up and floats away in the form of icebergs. The same phenomenon takes place during the fall of the tide, and, as the support of the water is withdrawn, another slice is removed. This discharge appears chiefly to occur immediately after half-tide; in both cases the amount broken off will therefore represent half the portion of ice which has advanced in the interval between one complete rise and fall of the tide. Broadly speaking, then, four periods of discharge may be said to occur every 24 hours. I endeavoured to estimate the width of the bergs collected in front of the glacier as we rowed through them on the evening after our return to the coast; many of these could not have been less than 8 to 10 feet across in their shortest diameter. If, therefore, we suppose these to represent the width of ice broken off during one rise or fall of the tide, this would give 32 to 40 feet as the amount of advance in 24 hours; or even supposing that these larger bergs represent a portion of the ice-front which resisted one rise or fall of the tide, and which would represent the advance during half a day, it would give 16 to 20 feet for the daily motion of the glacier. In addition, however, to the larger bergs, splinters of ice were constantly falling throughout the day; and I do not think, therefore, that an estimate of 25 feet for the motion of this glacier during every 24 hours would be excessive.

VI. Action of Sea-ice.

The relative amount of action produced by the various forms of sea-ice is difficult to differentiate; scratches found on the surface of submerged rocks may be due to either icebergs or floe-ice, or to movements taking place in the continuous sheet of ice occupying a bay in winter. Beautiful examples of scratching and grooving are to be found on the surface of some of the submerged limestone-beds which lie south-west of Coal Haven in King's Bay.

Since these are covered by water, except at very low tide, their glaciation cannot be attributed to the action of land-ice. They form the base from which a spit of shore composed of pebbles and boulders projects into the fjord, at low tide enclosing a lagoon. This ridge is chiefly composed of blocks of rock dropped by icebergs which have stranded in the shallow water at the edge of the reef and partially melted before being carried out to sea. It is therefore probable that the scratches, which here run parallel to the coast-line, are produced by these icebergs. Some, however, which I observed running at right angles to the coast, may have been produced by the pressure of the ice covering the bay in winter due to any sudden increase in the cold, when a direct thrust would take place on shore, the centre of the bay becoming the radiating-point, in a manner similar to that suggested by Mr. Lamplugh in the case of the ice-sheet that occupied the North Sea during the Glacial Period.

As the country is known to have been rising for some time past, I am inclined to think that much of the rounding of the lower slopes surrounding the bay has been produced by ice of this description; and I would suggest that the smooth contours of the islands to the north (and especially Walden Island, which we visited during our first expedition to the country) were impressed on those hard Archæan rocks by sea-ice during the elevation, and not by glaciers originating on the mainland. It would be interesting to determine, if possible, whether any particular boulder has received its characteristic glaciation during the forward movement of a glacier or during its voyage on an iceberg; but no definite distinction between the marks produced by these different modes of origin seems to exist. I was impressed, however, by the fact that the majority of the boulders collected from icebergs by the Jackson-Harmsworth Expedition appeared to possess one side much more definitely planed and polished than the rest of the block, and I found the same characteristic among many of the boulders which I examined on the spot. This feature is what we might expect in blocks carried by floating ice and ground against projecting reefs under water, for in this case the boulder would probably retain its original position in the ice until deposited on the melting of the berg, and would not be constantly rolled over in the ice in the way which must usually occur with fragments embedded in the lower layers of a moving mass of land-ice. It is possible that this fact may help to decide whether in some Glacial deposits the boulders have originated in land-glaciers or floating ice.

VII. Rock-sculpturing above the Snow-line. (Pl. XLVIII, fig. 1.)

The snow-line in Spitsbergen is usually stated to reach sea-level. This is perhaps true as regards North-east Land, which appears to be covered by a continuous ice-sheet. In West Spitsbergen, however, especially on the western coast and in the neighbourhood of Ice Fjord, this is certainly not the case. The snow-line here lies somewhere about 1200 to 1500 feet above sea-level, and usually rises even higher by the end of August. The mountain-slopes along the coast at Mount Starashchin, King's Bay, and elsewhere, and the lower slopes of the valleys of the interior, namely, Sassendal and Advent Vale, exhibit typical curves produced by the action of running water.

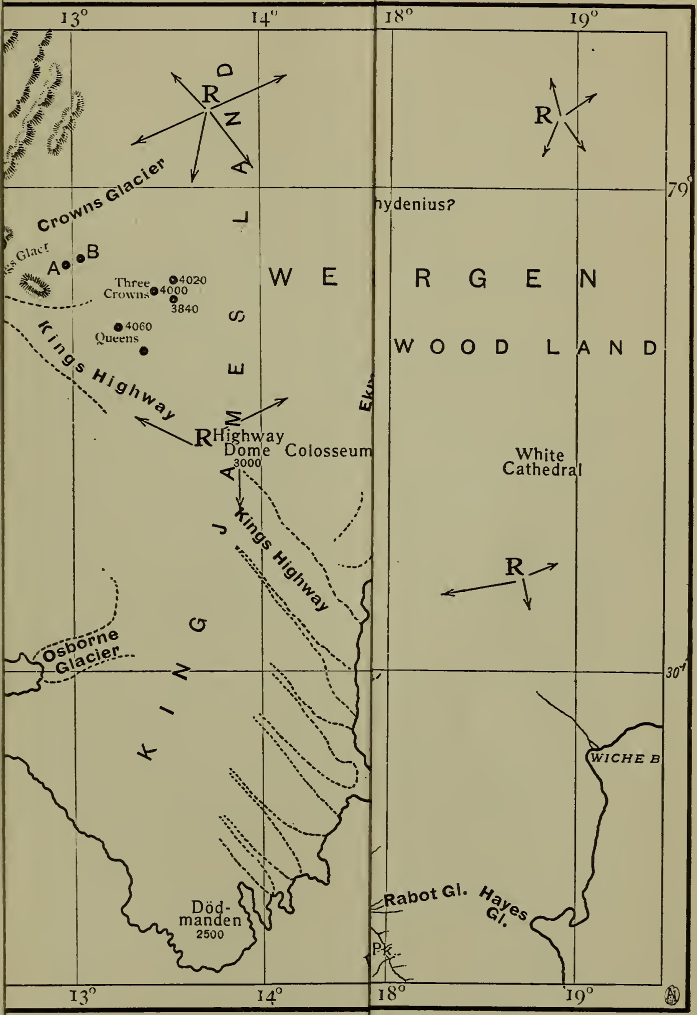
The character of the scenery above the snow-line presents a marked contrast to these flowing curves. They are replaced by angular contours and vertical precipices produced by the action of frost alone. These wild and jagged outlines are perhaps most noticeable in the cleaved and foliated Archæan and Hekla Hook formations, a good example of the latter occurring in the range of the Hornsunds Tinde in the south of the island (Pl. XLVIII, fig. 1).

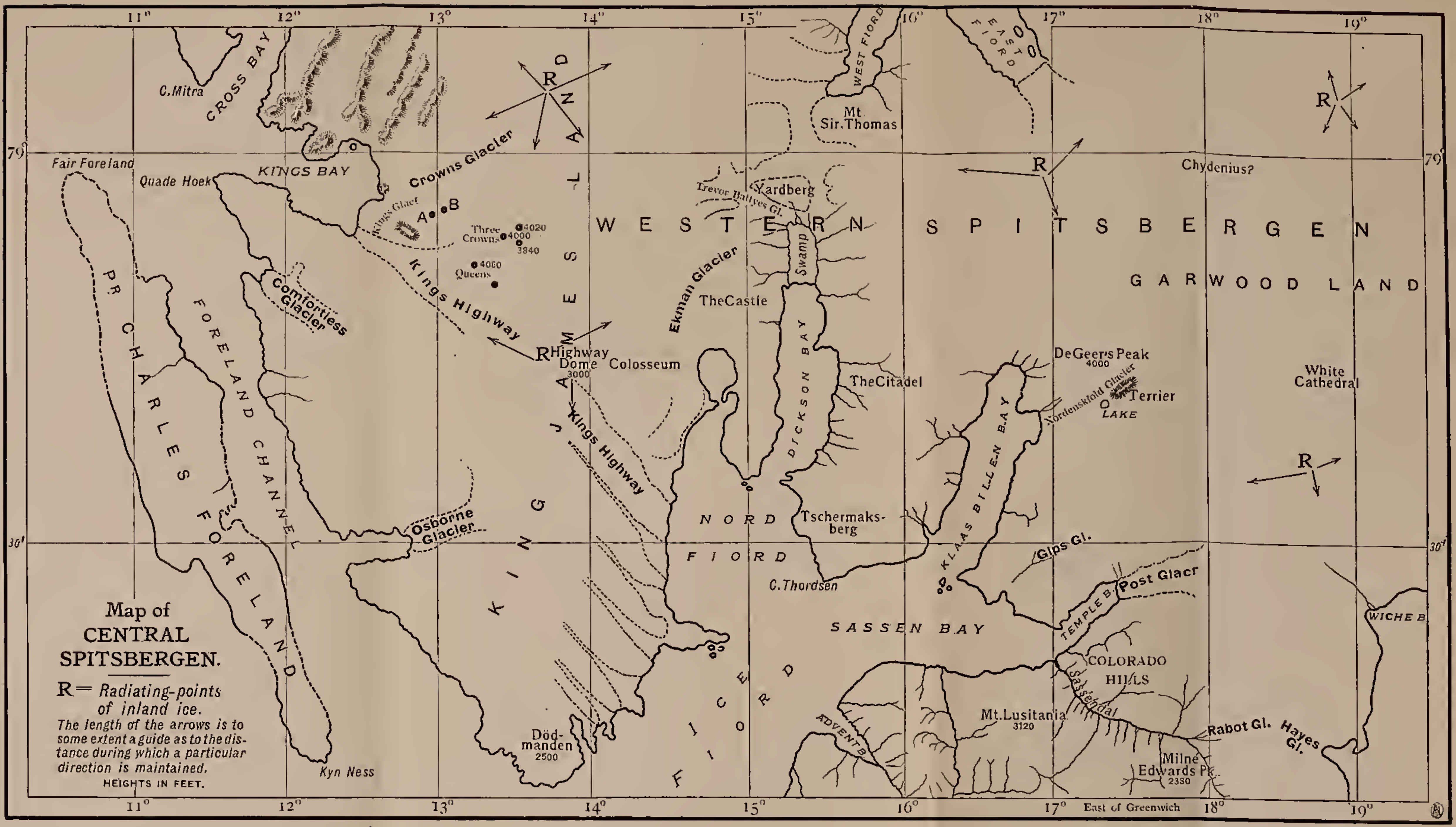
The rocks of the Carboniferous dolomite-series are carved into pyramidal masses with vertical chimneys and horizontal ledges, recalling the well-known Dolomites in the Austrian Tyrol, and frequently presenting inaccessible faces. Many fine examples of peaks of this type occur in the centre of King James's Land, where the Three Crowns and their neighbouring summits have been carved out of an horizontal plateau of Permo-Carboniferous strata which once completely covered this district. The curved slopes of the pedestals on which they stand are formed of copious screes from frost-riven Devonian shales. On the upper plateaux that flank the Sassendal and Advent Vale the same effect of frost is conspicuous: in this case, however, the horizontal bedding and unequal hardness of the Triassic and Jurassic rocks have caused a series of terraces to be produced.

In speculating as to whether, in former times, the ice-sheets attained a greater thickness than at present and submerged the mountain-tops which now stand out as nunatakkr, it has been suggested that this angularity of the peaks rising from the midst of the ice demonstrates their continued freedom from any covering of ice even during Glacial times.

The more the district is studied, however, the more evident becomes the fact that denudation is proceeding with a rapidity difficult for those to realize who are only acquainted with weathering in a temperate climate; and I do not think that any argument can be drawn from the present angularity of the peaks above the snow-line. It is only necessary to camp in the immediate proximity of a nunatak like the Pretender in King James's Land, where fragments are falling continuously, and rock-avalanches occur every few hours; or to note the size of the medial moraines draining these rock-islands—to realize that a very few years would suffice to remove entirely any surface-features which might have been

Geol. Soc. Vol. LV, Pl. XLI.





Map of
CENTRAL
SPITSBERGEN.

R = *Radiating-points of inland ice.*
The length of the arrows is to some extent a guide as to the distance during which a particular direction is maintained.
HEIGHTS IN FEET.

impressed on them in former times. The presence of boulders of diabase on the plateaux of Sticky Keep in the ice-free Sassendal at an elevation of 1500 feet, where they must either have been raised nearly 1000 feet, unless the valley has since been excavated to that depth, or carried up on the surface of a glacier which attained that thickness, not to quote other instances observed on the island, is a sufficient proof of the former much greater extent and thickness of the ice in the district.

EXPLANATION OF PLATES XLI–XLVIII.

Plate XLI.

Outline-map of Central Spitsbergen, on the scale of about 14 miles to the inch, showing the radiating-points of the inland ice.

Plate XLII.

Panoramic view showing the main ice-streams entering the eastern end of King's Bay.

The ice in the immediate foreground is derived from the local glaciers at the foot of Mount Neilson. Its motion is slow, it is uncrevassed, and it terminates on a flat of raised-beach material. The bulk of the glacier beyond (Crowns Glacier) is derived from the Highway Glacier and the ice-sheets north and west of the Pretender Range. Its motion is much slower, and it terminates in a vertical face from which icebergs are calved. The estimated advance of the main mass is 25 to 30 feet in 24 hours.

The mountain-ranges extending across the island from Mount Neilson are composed of Hekla Hook Beds, and form the southern boundary of the King's Highway. The range marks a line of thrust against which patches of Carboniferous rocks have been let down, and this thrust-plane no doubt determined the original direction of King's Bay. Views obtained from the summit of Mount Neilson show that the country south of the range is mountainous, and not covered with an ice-sheet as indicated on the chart.

The centre of the view is occupied by two nunatakkr. The larger of these, on the right, is formed of Carboniferous Limestone, exhibiting a thrust-plane between the lower and upper beds. The more distant nunatak, on the left, is of Devonian conglomerate similar to that of which the islands in the bay are formed.

Plate XLIII.

The terminal front of King's Glacier: the thickness of the ice showing above sea-level is about 100 feet.

I = South-east Islands (see panorama, Pl. XLII).

M = Englacial moraine, elevated and thrown out at the end of Neilson Glacier, about 50 or 60 feet above sea-level.

Plate XLIV.

Icebergs calved from King's Glacier at half-tide. View taken at midnight, looking south-east from the north-west islands of Devonian conglomerate shown in the panorama (Pl. XLII).

The undulating shore-line AB is formed of Permo-Carboniferous dolomitic limestone, and the thrust-plane already mentioned runs between it and the mountain-range. From the icebergs shown in this plate the approximate rate of motion of King's Glacier was deduced. Moraine-material is conspicuously present on many of them, and some of it can be seen stranded in the foreground. Boulders from this showed the characteristic unilateral striation to which reference is made on p. 687. Attention is also directed to the Corrie Glacier, examples of which were described in a former paper, Quart. Journ. Geol. Soc. vol. liv (1898) p. 200.

PLATE XLV.

A collapsed ice-tunnel near Pretender Peak.

The view is taken inside the tunnel, which is about 8 feet high: other tunnels are seen in the distance.

PLATE XLVI.

Fig. 1. Ice-tunnels formed against the Pretender Range.

Bird's-eye view, to show the manner in which the ice-bridges are ridged up into parallel tunnels by the pressure of the ice against the barrier opposed to it by the range. A nearer view of some of these tunnels is shown in Pl. XLV.

Fig. 2. View of nunatakkr causing elevation of englacial material.

This not only constitutes an interesting example of the way in which the ice is ridged up on the impact-face of the nunatak (A), but affords a striking proof that the moraine-material frequently found in connexion with this upridging of the ice is not thrown off from the nunatak around which it occurs, but is in reality upraised englacial material. In the present example, the upper nunatak (B) and the moraine that encircles the impact-face of A are both formed of Archæan rock, while the nunatak A is composed of Carboniferous dolomite.

PLATE XLVII.

Fig. 1. Surface-stream on Highway Glacier. (See p. 685.)

Above the level of crevassed glaciers the ice-sheet is entirely drained by streams of this description, which frequently contain waterworn glacial material. The width of the torrent is about 15 feet, and the depth of the channel about 14 feet.

Fig. 2. Englacial stream with moraine, King's Glacier.

The view shows an ice-tunnel 15 feet in diameter, which has been excavated by water escaping from a glacial lake immediately to the right of the picture. The moraine from a neighbouring nunatak is being carried into the tunnel, and waterworn fragments were found some distance from the entrance. The material lying on the floor of the channel is heaped up at right angles to the direction of the valley.

PLATE XLVIII.

Fig. 1. The range of the Hornsunds Tinde, viewed from its southern extremity on Mount Hedgehog.

This range has been entirely carved by frost out of Hekla Hook Beds, along the bedding and jointing shown in the picture, producing what has been aptly termed houseroof structure.

The ice-sheet out of which the range rises is seen in the distance. In the immediate foreground the almost vertical precipices are coated with hoar-frost, which has formed to a depth in some places of 18 inches, a product of the fogs that enshrouded the mountains during the three weeks preceding the day on which the photograph was taken (see Alp. Journ. vol. xviii, 1897, p. 373).

Fig. 2. One of the erratics of the Archæan moraine, Nordenskjöld Glacier.

The boulder shown in this figure is one of the series described in the text (p. 684) as forming an independent moraine composed of isolated polished Archæan blocks, 4 to 6 feet in diameter. The view is taken looking down the glacier, towards the coast.

[For other views of the district, supplementing in many respects those here reproduced, the reader may consult Geogr. Journ. vol. xii (1898) pp. 152–155].

Hook.

Island.

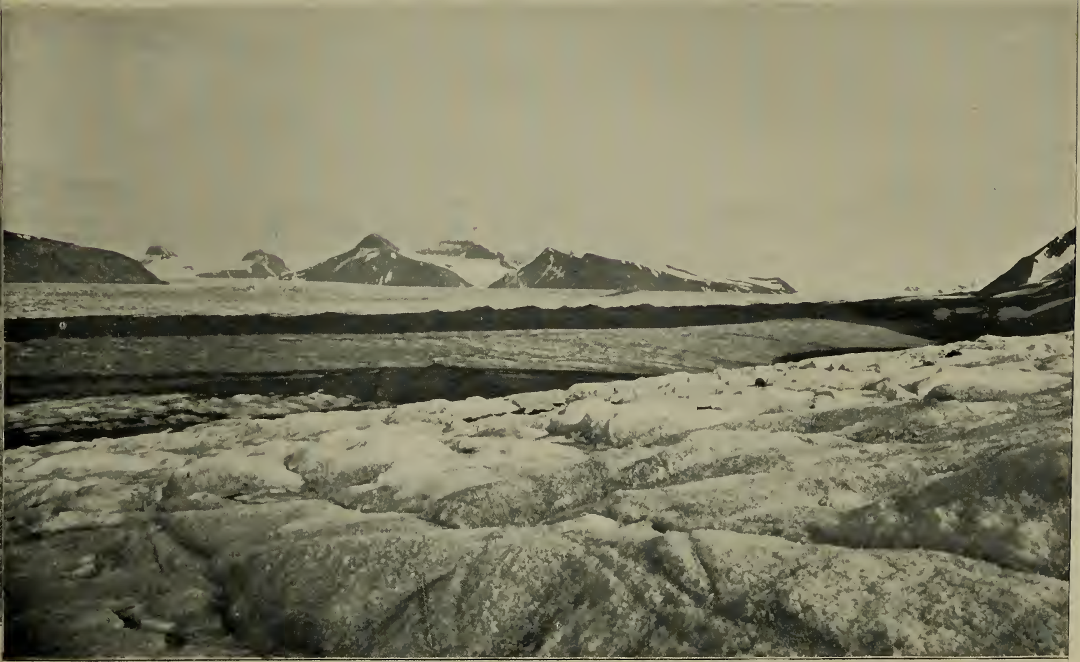
Islands.

Devonian

Carboniferous Nunatak.

N. W. Radiating Point

SWAN ELECTRIC ENGRAVING CO.

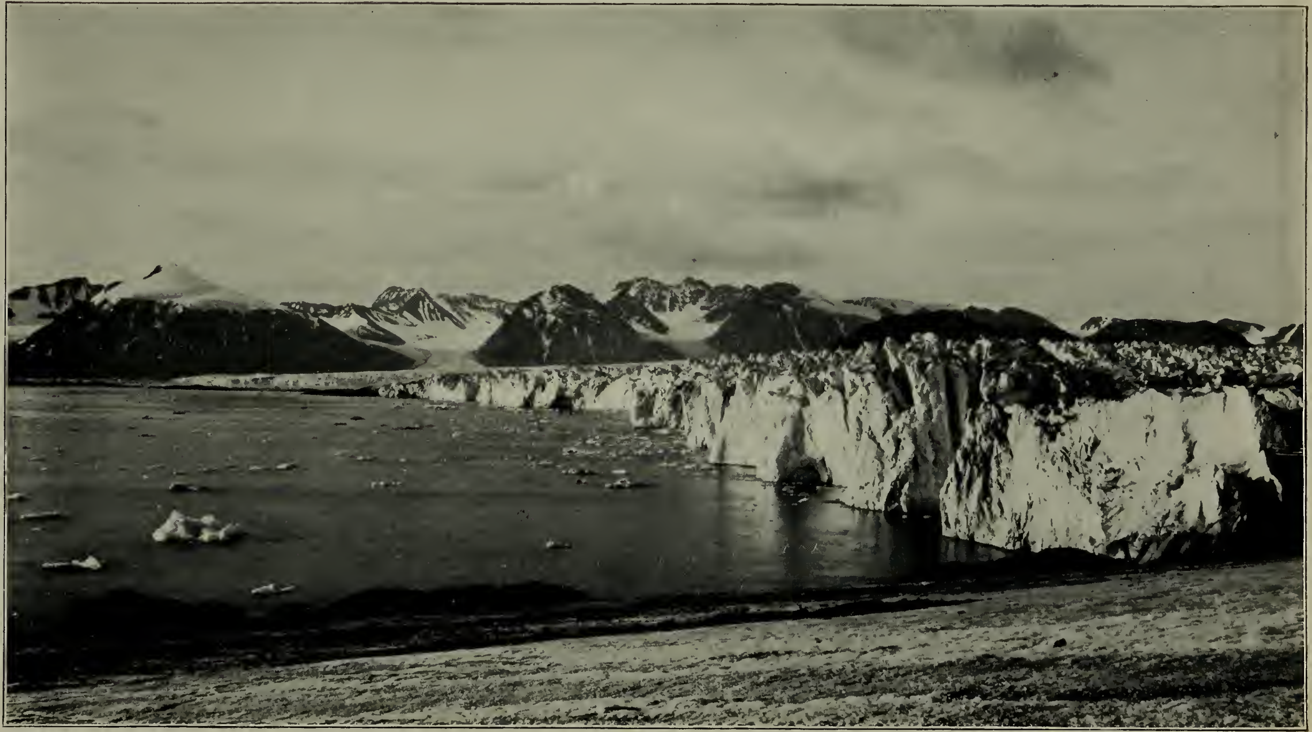


NEILSON GLACIER.

SWAN ELECTRIC ENGRAVING CO.

VIEW OF THE GLACIER-SYSTEMS OF KING'S BAY.

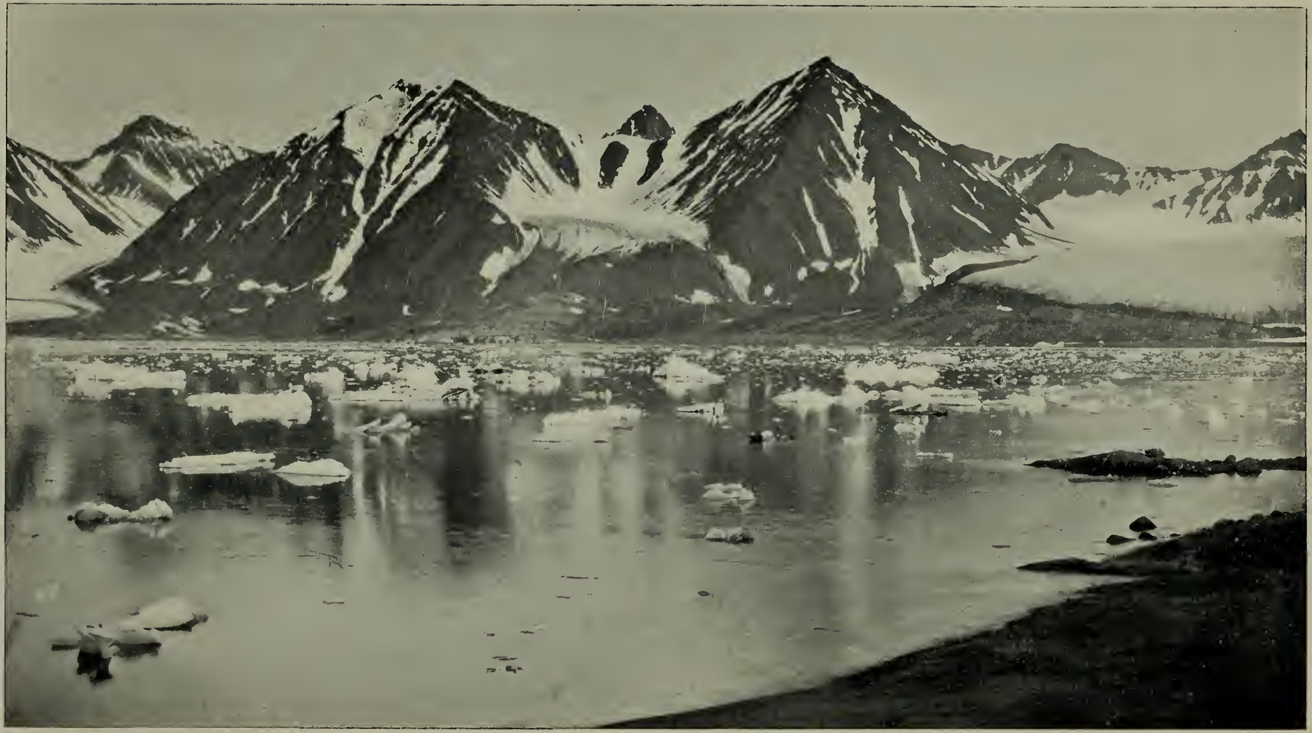
PHOTO BY E. J. GARWOOD.



SWAN ELECTRIC ENGRAVING CO.

THE TERMINAL FRONT OF KING'S GLACIER.

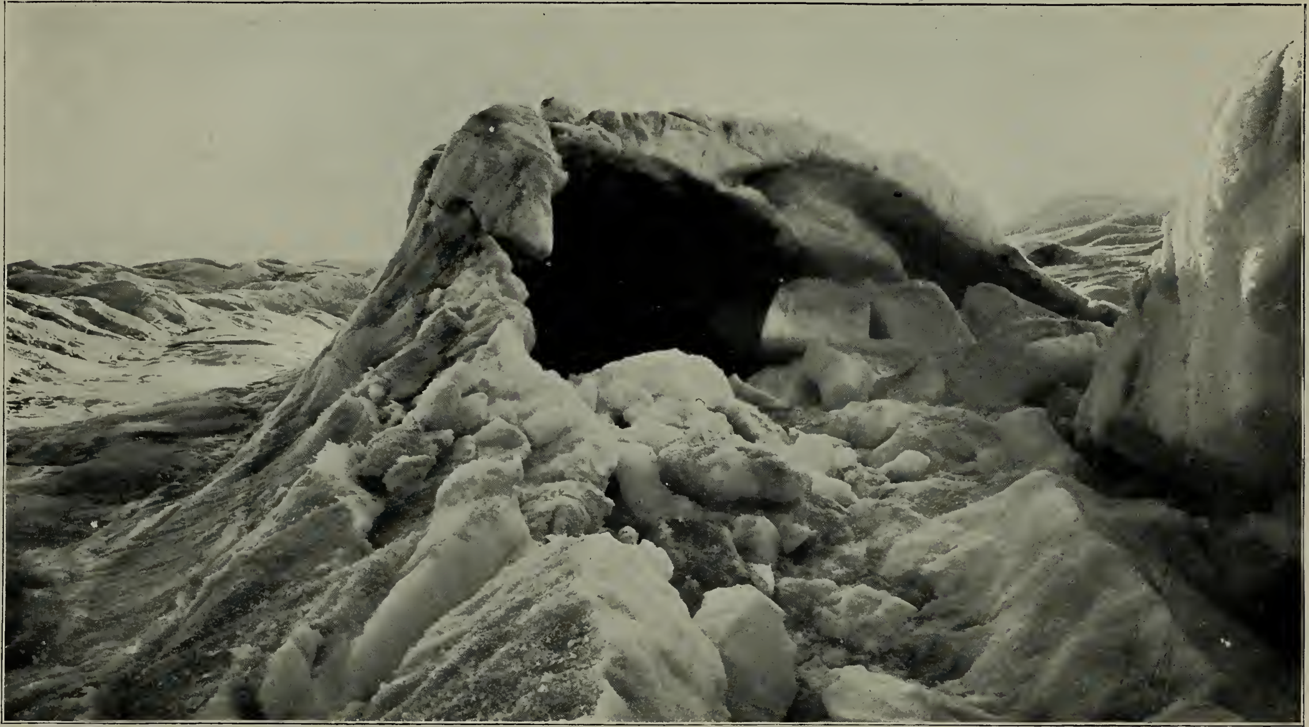
PHOTO BY E. J. GARWOOD.



SWAN ELECTRIC ENGRAVING CO.

ICEBERGS CALVED FROM KING'S GLACIER AT HALF-TIDE.—View taken at Midnight.

PHOTO BY E. J. GARWOOD.

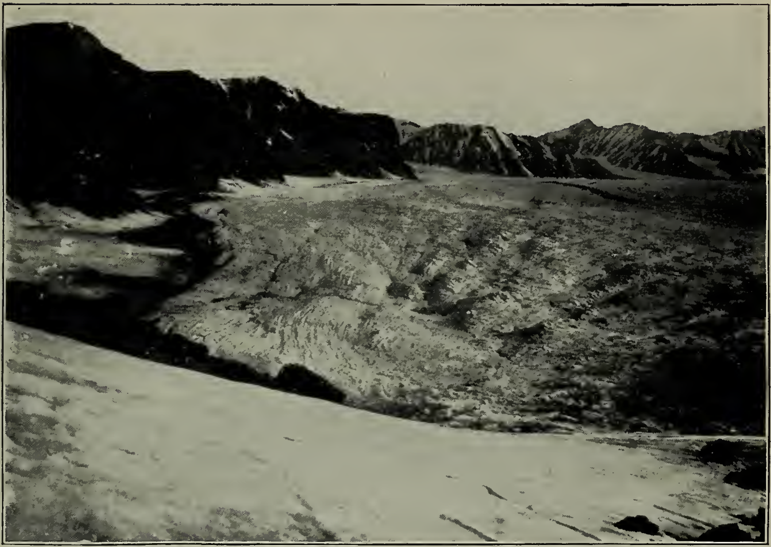


SWAN ELECTRIC ENGRAVING CO.

A COLLAPSED ICE-TUNNEL, NEAR PRETENDER PEAK.

PHOTO BY E. J. GARWOOD.

Fig. 1.



ICE-TUNNELS FORMED AGAINST THE PRETENDER RANGE.

Fig. 2.

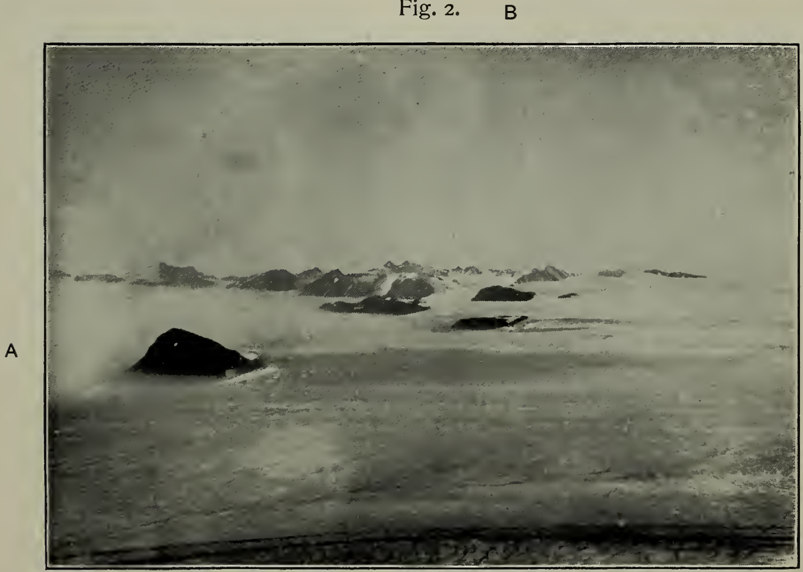


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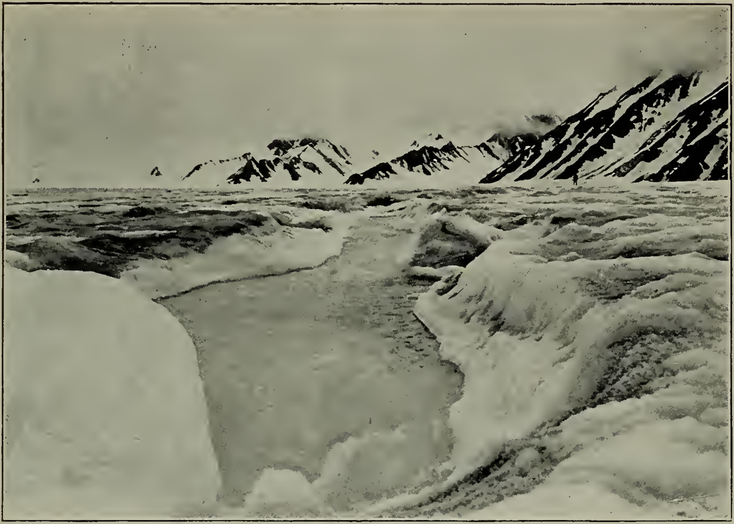
PHOTO BY E. J. GARWOOD.

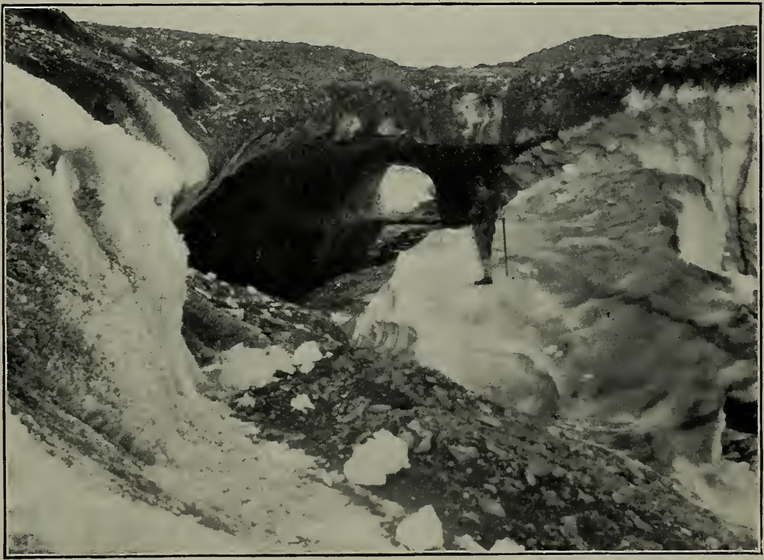
VIEW OF NUNATAKKR CAUSING ELEVATION OF ENGLACIAL MATERIAL.

Fig. 1.



SURFACE-STREAM ON HIGHWAY GLACIER.

Fig. 2.



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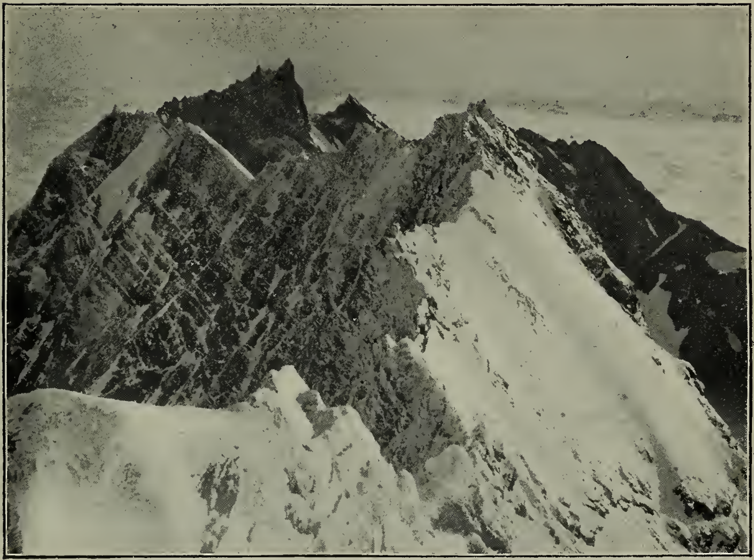
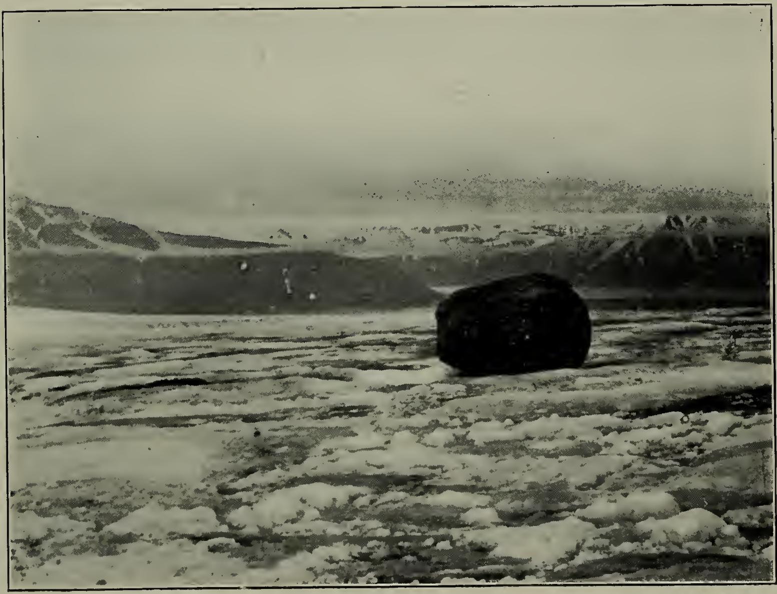
ENGLACIAL STREAM WITH MORAINE, KING'S GLACIER.

Fig. 1.



THE RANGE OF THE HORNSUNDS TINDE, FROM MOUNT HEDGEHOG, SHOWING FROST-DENUDATION.

Fig. 2.



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ONE OF THE ERRATICS OF THE ARCHÆAN MORAINE, NORDENSKJÖLD GLACIER.

Discussion.

Mr. Marr said that not only had the Author confirmed the observations of others, but he had also made many new observations. Every glacial area should be studied by geologists, and each would no doubt contribute new facts of geological importance. The Author had spent two seasons in Spitsbergen; he was now about to start for the Himalayas, and he (the speaker) felt sure that the Fellows of the Society would wish him a successful expedition. In conclusion he wished to thank the Author for the admirable way in which he had presented his paper to the Society.

Mr. Lamplugh expressed his gratitude to the Author for the new facts, which all tended to confirm the deductions to be drawn from the glacial phenomena of parts of the British Islands with which he was acquainted. Time alone limited the number of pertinent questions which might be asked in this connexion: he must be content now to enquire, first, whether the Author had observed any instance where the streams flowing on the ice-sheets had intersected emerging ridges of solid rock; and, secondly, to what extent the ice-fields would grow again under present conditions if they were entirely removed in this area.

Mr. Salter asked whether the Author had seen anything resembling the Boulder Clay and glacial gravel-deposits of Eastern and Central England, while examining the débris from the inland ice-sheets described by him. Such rapid denudation and other phenomena shown to exist in Spitsbergen, acting on the soft Jurassic Clays of Central England, would certainly be sufficient to bring about many, if not all, the effects of glacial and torrential action observed.

The Author, in reply to Mr. Lamplugh, thought that should an englacial river cut down to a transverse ridge occurring under the ice, such a col as was suggested would be produced; no such case, however, was actually met with. He was strongly of opinion that the ice-sheets described were at one time much more extensive than at present, and that the greater part of the ice now covering the country was the result of accumulation in former times; were the district freed from ice and given a fresh start at the present time, he did not think that ice would now accumulate to any great extent. This was proved by the existence of the ice-free area traversed in 1896, when the island was crossed from coast to coast without encountering more than one glacier which covered the extreme watershed.